Method for manufacturing a light emitting display

The invention relates to a method for manufacturing a light emitting display on a substrate.

The invention further relates to a light emitting display and to an electric device comprising such a display.

US 5,962,970 discloses a method for manufacturing an organic display panel wherein first display electrodes, organic function layers including at least one organic electroluminescent medium formed on exposed portions of the first display electrodes and second display electrodes formed on the organic function layers are deposited on a substrate. Electrically insulating ramparts projecting from the substrate to a height up to 0.5μm are employed for electrically disconnecting the adjacent second display electrodes, which are deposited by evaporation of a metal.

However, this method for manufacturing a light emitting display has several disadvantages relating to e.g. the use of the electrically insulating ramparts. One of these disadvantages is the limitation on the thickness for the second electrode as a result of which the electrical resistance of this second electrode is high. Moreover, the ramparts cause problems in sealing or encapsulating the light emitting display from environmental influences resulting in expensive sealing arrangements. Further the ramparts may be unstable leading to requirements for careful handling of the structures. Also processing flexibility for the light emitting display has some limitations due to the susceptibility of the light emitting layer segments of the display.

It is an object of the invention to provide an improved method for manufacturing a light emitting display wherein at least one of the above mentioned disadvantages is avoided or at least reduced.

This object is achieved by providing a method for manufacturing a light emitting display on a substrate comprising the steps of:

– depositing a first electrode layer on or over said substrate;

- forming a plurality of light emitting layer segments on or over at least a part of said first electrode layer;
- applying at least one protective layer on or over at least one of said light emitting layer segments;
- depositing a second electrode layer.

The invention further relates to a light emitting display comprising:

- a substrate;
- a first electrode layer deposited on or over said substrate;
- a plurality of light emitting layer segments formed on or over said first electrode layer;
- at least one protective layer applied on or over at least some of said light emitting layer segments;
- a second electrode layer.

By providing a protective layer over the light emitting layer segments more freedom with regard to processing conditions is obtained in depositing and/or patterning of subsequent layers, since the susceptible light emitting layer segments are protected by the protective layers. Processing using wet etching means can e.g. be performed for structuring of layers applied after the appliance of the protective layer. Preferably the light emitting layer segments are entirely covered by the protective layer.

In a preferred embodiment of the invention the protective layer comprises or consists of molybdenum or titanium. Molybdenum or titanium layers or layers comprising these materials are suitable to protect the light emitting layer segments for wet etching means.

In a preferred embodiment of the invention the second electrode layer is aluminium and/or is patterned by photolithography and subsequent etching. Patterning of the second electrode layer by such a process has become possible by the application of the protective layer on the light emitting layer segments, protecting the susceptible segment from e.g. wet etching agents. Thus, the prior art electrically insulating ramparts do not have to be applied for patterning the second electrode layer as a result of which the thickness of this second electrode layer can be significantly increased. A thick second electrode layer, larger than $0.5\mu m$, and preferably in the range of 0.5 to $3\mu m$, leads to a low electrical resistance and a short RC-time, which is important for high switching frequencies. Moreover the shape of the prior art ramparts provided problems with regard to obtaining an appropriate sealing film for encapsulating the structure. Photolithographic patterning of the second electrode layer

provides an appropriate starting point, e.g. a smooth surface, for further encapsulation of the light emitting device.

In an embodiment of the invention the patterned second electrode layer comprises recesses wherein the protective layer is removed. A sealing film for encapsulation of the resulting structure is preferably deposited on the patterned second electrode layer and in the recesses. The sealing film can be made thin, e.g. 0.5μm, in contrast to the typically applied thick encapsulation arrangements using e.g. individual metal caps for each structure or light emitting device on the display with a thickness in the range of 0.3 to 1mm. The individual metal caps are typically glued to the substrate and comprise a getter material. The approach according to this embodiment enables encapsulation of substantially all the structures of the display without using a getter material, resulting in a considerable cost efficiency.

It should be appreciated that the previous embodiments, or aspects thereof, may be combined.

The invention further relates to an electric device comprising a light emitting display as described in the previous paragraph. Such an electric device may relate to handheld devices such as a mobile phone, a Personal Digital Assistant (PDA) or a portable computer as well as to devices such as a Personal Computer, a television set or a display on e.g. a dashboard of a car.

WO 00/16938 discloses a method for manufacturing a colour organic light emitting device structure, wherein a passivation layer permitting lithographic patterning of colour changing media using wet processing methods is employed. However, this passivation layer is deposited over the second electrode layer of the OLED drivers integrated in the substrate.

US 5,998,926 discloses a method for manufacturing an organic electroluminescent device wherein the cathode is formed into a fine pattern by photolithography. However, the cathode layer is deposited directly on the substrate and is patterned before the organic electroluminescent layer is provided.

The invention will be further illustrated with reference to the attached drawing, which shows a preferred embodiment according to the invention.

Figs. 1-4 schematically illustrate first to fourth manufacturing steps for a light emitting display;

Fig. 5 schematically illustrates a top view at the fourth manufacturing step according to Fig. 4.

Fig. 6 schematically illustrates a fifth manufacturing step for a light emitting display;

Fig. 7 schematically illustrates an enlarged view of a light emitting element during the fifth manufacturing step;

Fig. 8-13 schematically illustrate sixth to eleventh manufacturing step for a light emitting display;

Fig. 14 schematically illustrates a light emitting display.

In Fig. 1 a substrate 1 is provided for manufacturing the light emitting display 14 (shown in Fig. 14). Preferably, the substrate 1 is transparent with respect to the light to be emitted by the light emitting layer segments 7R, 7B (shown in Fig. 6). Suitable substrate materials include synthetic resin which may or may not be flexible, quartz, ceramics and glass. The total thickness of the substrate typically ranges from 100 to 700 μm.

A first electrode layer 2, commonly referred to as the anode, is deposited on or over the substrate 1, e.g. by vacuum evaporation or sputtering. The first electrode layer can subsequently be patterned by photolithography. Preferably the first electrode layer 2 is transparent with respect to the light to be emitted by the light emitting layer segments in operation of the light emitting display 14. For example, a transparent hole-injecting electrode material, such as Indium-Tin-Oxide (ITO), is used. Conductive polymers such as a polyaniline (PANI) and a poly-3,4-ethylenedioxythiophene (PEDOT) are also suitable transparent hole-injecting electrode materials. Preferably, a PANI layer has a thickness of 50 to 200 nm, and a PEDOT layer 100 to 300 nm.

In Fig. 2 a next manufacturing step is shown, wherein a low resistive metal, such as a Molybdenum/Aluminium/Molybdenum (MAM) layer 3 is deposited on or over the first electrode layer 2. The MAM layer 3 is subsequently defined photolithographically, e.g. at the positions where no light is to be generated. MAM layer 3 is applied for contacting purposes and for decreasing the electrical resistance to the first electrode layer 2. The total thickness of MAM layer 3 typically ranges up to 0.5μm.

In Fig. 3 a next manufacturing step is shown, wherein an insulating layer, such as novolack or acrylate, is spincoated over the structure shown in Fig. 2 and is subsequently patterned by means of photolithography. The insulating layer is e.g. baked at 220°C for 30

minutes. In patterning the insulating layer delimiting means 4 define cavities or sites 5 between the delimiting means 4 for the light emitting elements 7R and 7B to be deposited further on. Moreover the delimiting means 4 assists in the separation of the second electrode layer as will be described in more detail below. The widths of the delimiting means 4 is typically 20μm with a thickness of about 3μm. The insulating layer or delimiting means 4 is of a hydrophilic nature, i.e. it may exert an attractive force on liquid state materials.

In Fig. 4 a next manufacturing step is shown wherein parts 6, repelling the fluid light emitting substance to be deposited afterwards are applied on or over the delimiting means 4, bounding the sites 5 of the light emitting elements. The repellent parts 6 may e.g. be strips of repellent material. These repellent parts 6 may be obtained in various ways. The repellent parts 6 are the subject of a co-pending application of the applicant. The width of the repellent part 6 may range from 5-15μm, e.g. 10μm.

Fig. 5 shows a top view of a part of the light emitting display after the repellent parts 6 have been applied. In Fig. 5 it is illustrated that the repellent parts 6 can be applied to bound the cavities or sites 5 in a number of ways. Fig. 5 shows as examples bounding by the repellent parts 6 along the entire circumference of the sites 5 (left-hand column of cavities or sites 5) and a partial bounding by the repellent parts 6 (right-hand column of cavities or sites 5). The way in which the repellent parts 6 bound the sites 5 may be dependent on the process chosen for deposition of the fluid light emitting substance or the arrangement of colours for the various cavities or sites 5. If e.g. the same colour is to be deposited in a column, repellent parts 6 that only partially bound the sites 5, according to the right-hand column of Fig. 5, may be used, since flow of material between the sites 5 in this column may not be harmful.

In Fig. 6 a next manufacturing step is shown, wherein the fluid light emitting substance is deposited in the cavities or at the sites 5 to obtain the light emitting elements or layer segments 7. It is noted that a light emitting element or layer segment 7 may comprise several conductive polymer layers, such as a polyethylenedioxythiophene (PEDOT) layer and a polyphenylenevinylene (PPV). For a colour light emitting display different materials may be used. In Fig. 6 light emitting element or layer segment 7R refers to a red-light emitting material and light emitting element or layer segment 7B refers to a blue light emitting material. Conventionally a third material G emitting green light is applied as well. The light emitting materials R, G and B are preferably electroluminescent materials and are deposited by inkjet-printing. The length of a light emitting element is e.g. 240μm.

Fig. 7 shows a detailed view of a cavity or site 5, wherein the fluid red light emitting substance has been deposited and is depicted in various stages of the drying process after deposition. Due to evaporation of the solvents used, shrinkage, indicated by the arrow, occurs leaving the red light emitting material behind in the cavity or site 5. The light emitting material layer is necessarily somewhat oversized with respect to the site 5 to avoid shortcuts emanating if the light emitting display is operated, i.e. a voltage is applied over the light emitting layer. The oversized light emitting material is obtained, since the delimiting means 4 is of a hydrophilic nature.

However, the fluid light emitting substance of light emitting element or layer segment 7R should not flow to an adjacent light emitting element or layer segment 7B comprising a light emitting of different colour. It is illustrated that this effect is achieved by employing hydrophobic barriers as repellent parts 6.

In Fig. 8 a next manufacturing step is shown wherein metallization is applied on or over the light emitting elements or layer segments 7R and 7B. This metallization consists e.g. of a barium layer 8' for reducing the barrier level for injecting electrons, on top of which a second electrode layer 9, commonly referred to as the cathode, is deposited. However, in the manufacturing process applied here an additional molybdenum or titanium layer 8" is applied, acting as a diffusion barrier for protecting the light emitting elements or layer segments 7R and 7B for wet etching solutions. In Fig. 8 the barium layer 8' and the titanium or molybdenum layer 8" are shown as a single layer 8. The thickness of the barium layer 8' is e.g. 5nm, of the titanium or molybdenum layer 8" e.g. 100nm and of the cathode layer 9 e.g. 2μm. Prior art cathode layers have a thickness of about 0.5μm maximum. As a result of the thick cathode layer 9 in this embodiment of the invention, the electrical resistance for applying a voltage to the light emitting element 7 has significantly decreased.

In Fig. 9 a next step of the manufacturing process is shown, wherein the cathode layer 9, is patterned. Cathode layer 9 is made of e.g. aluminium. Patterning of the cathode layer 9 is performed by photolithography followed by wet etching recesses 10 in the cathode layer 9. The wet etching process does not affect the light emitting elements or layer segments 7R and 7B, since the titanium layer or molybdenum layer 8" acts as a diffusion barrier to the wet etching means. For etching of aluminium a mixture of e.g. acetic acid, phosphoric acid, and nitric acid may be used. Typically, the parts of the patterned cathode layer 9 substantially cover the light emitting layer segments 7R, 7B entirely. Patterning can be performed such that the patterned parts of the cathode layer 9 are in correspondence with

the light emitting layer segments 7R, 7B, i.e. that light can be emitted by these light emitting layer segments 7R, 7B using the patterned parts of the cathode layer 9.

In Fig. 10 a next manufacturing process step is shown, wherein the protective layer 8 is partially removed at the recesses 10 by plasma etching in a CF4/Ar environment.

In Fig. 11 a next manufacturing process step is shown, wherein a SiN film 11 is deposited over the structure shown in Fig. 10. This film 11 hermetically seals the structure from liquid or moisture that may affect the light emitting layers or elements 7R and 7B, e.g. via the recesses 10. It is noted that the manufacturing process steps shown in Fig. 10 and 11 may be performed in combination by using a cluster tool system with e.g. an etching and a deposition tool module. In this case the structure is not exposed to air between etching of the diffusion barrier and hermetic sealing with SiN. The SiN layer 11 has a thickness of e.g. $0.5\mu m$. As an alternative oxinitride SiN(x)O(y) may be used for the sealing film 11. This small thickness of the film 11 is sufficient for sealing, since the prior art electrical insulating ramparts with their negatively shaped angles are no longer applied as a result of the new way of cathode structuring with the protective layer 8.

In Fig. 12 a next manufacturing process step is shown, wherein a protection layer 12 is applied on or over the structure shown in Fig. 11. This protection layer 12 is obtained e.g. by spincoating a resist or by laminating a dry film resist and has a thickness of e.g. $10\mu m$. Recesses 13 can be obtained by photolithography. The resist 12 is e.g. baked at 120°C for 30 minutes.

In Fig. 13 a final manufacturing process step is shown, wherein the SiN film 11 is partially removed at the positions where the cathode layer 9 is to be contacted by connecting leads for operating the light emitting display. SiN film 11 may e.g. be removed in a CF4 plasma.

In Fig. 14 a light emitting display 14, which may be a polymer or small molecule light emitting diode device is depicted as a part of an electric device 15. The light emitting display 14 is e.g. a colour display comprising display pixels 16 arranged in a matrix of rows and columns comprising red, green and blue light emitting layer segments 7R, 7G and 7B. These light emitting layer segments may be light emitting diodes. It is noted that the light emitting elements 7R, 7G and 7B may be arranged in several configurations to form a display pixel 16, such as a rectangular or a triangular configuration. The light emitting layer segments 7R and 7B can be operated by applying signals to the first electrode layer 2 and/or the second electrode layer 9 in an appropriate manner.

For the purpose of teaching the invention, a preferred embodiment of a method for manufacturing a light emitting display has been described above. It will be apparent for the person skilled in the art that other alternative and equivalent embodiments of the invention can be conceived and reduced to practice without departing from the true spirit of the invention, the scope of the invention being only limited by the claims.